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THE COMBUSTION OF ORGANIC POLYMERIC MATERIALS. IGNITION PROPERT--ETC(U)
AUG 78 J R BROWN, E P GELLERT

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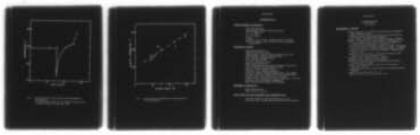

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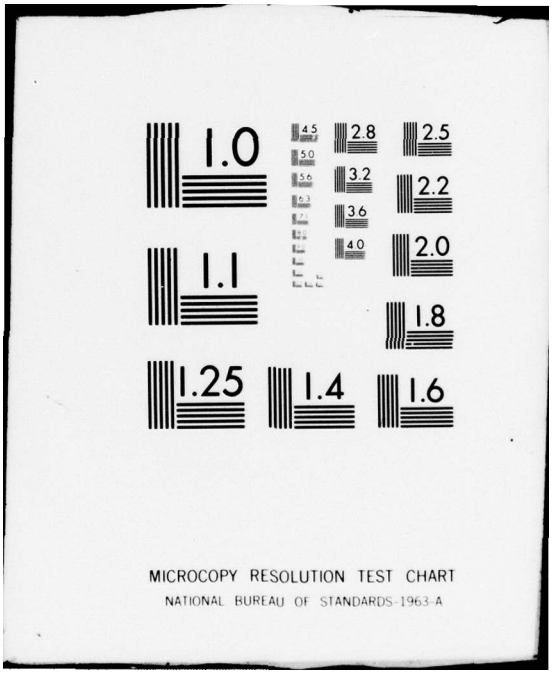
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TECHNICAL NOTE

MRL-TN-414

THE COMBUSTION OF ORGANIC POLYMERIC MATERIALS. IGNITION PROPERTIES

James R. Brown and Evan P. Gellert

Approved for Public Release

AUGUST, 1978

(12)

DEPARTMENT OF DEFENCE

MATERIALS RESEARCH LABORATORIES

(9) TECHNICAL NOTE

(14) MRL-TN-414

LEVEL II

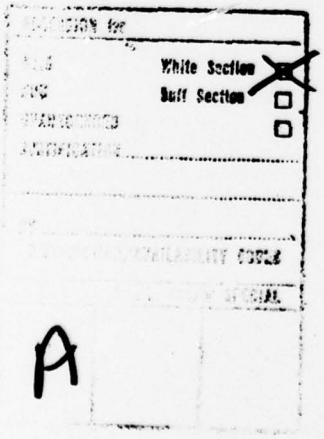
(6) THE COMBUSTION OF ORGANIC POLYMERIC MATERIALS.
IGNITION PROPERTIES.

(10) James R./Brown and Evan P./Gellert

(12) 16p. (11) Aug 78

ABSTRACT

The ignition properties of a number of organic materials of interest to Navy, including panelling materials, adhesives, unfilled and filled polymers, and flexible cellular polymers, have been determined in a hot-air furnace. The method provides a measure of piloted and non-piloted ignition temperatures of polymeric materials under controlled laboratory conditions. Values obtained represent the lowest ambient air temperatures that cause ignition under the conditions of the test and can be of considerable value in assessing and comparing the burning behaviour of materials.



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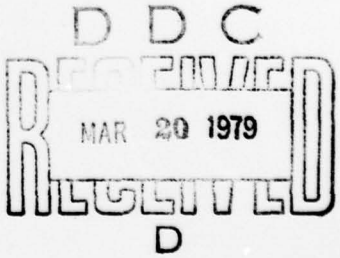

POSTAL ADDRESS: Chief Superintendent, Materials Research Laboratories
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DOCUMENT CONTROL DATA SHEET

Security classification of this page: UNCLASSIFIED

1. *DOCUMENT NUMBERS:*
   a. *AR Number:* AR-001-351
   b. *Series & Number:* TECH.NOTE MRL-TN-414
   c. *Report Number:* MRL-TN-414

2. *SECURITY CLASSIFICATION:*
   a. *Complete document:* UNCLASSIFIED
   b. *Title in isolation:* UNCLASSIFIED
   c. *Abstract in isolation:* UNCLASSIFIED

3. *TITLE:*
   THE COMBUSTION OF ORGANIC POLYMERIC MATERIALS. IGNITION PROPERTIES

4. *PERSONAL AUTHOR(S):*
   BROWN, James R. and
   GELLERT, Evan P.

5. *DOCUMENT DATE:* AUGUST, 1978

6. *TYPE OF REPORT & PERIOD COVERED:*

7. *CORPORATE AUTHOR(S):*
   Materials Research Laboratories

8. *REFERENCE NUMBERS:*
   a. *Task:* NAV 74/008
   b. *Sponsoring Agency:* DEPT. OF DEFENCE (NAVY OFFICE)

9. *COST CODE:* 374700

10. *IMPRINT (Publishing establishment)*
    Materials Research Laboratories,
    P.O. Box 50, Ascot Vale, Vic.3032
    AUGUST, 1978

11. *COMPUTER PROGRAMME(S):*
    (Title(s) and language(s)):

12. *RELEASE LIMITATIONS (of the document):*
    Approved for Public Release

12-0. *OVERSEAS:* N.O. [ ] P.R. [1] A [ ] B [ ] C [ ] D [ ] E [ ]

13. *ANNOUNCEMENT LIMITATIONS (of the information on this page):*
    No Limitation

14. *DESCRIPTORS:*
    Organic materials; Ignition temperature; Combustion; Fire hazards.

15. *COSATI CODES:* 1109, 1312

16. *ABSTRACT (if this is security classified, the announcement of this report will be similarly classified):*

The ignition properties of a number of organic materials of interest to Navy, including panelling materials, adhesives, unfilled and filled polymers, and flexible cellular polymers, have been determined in a hot-air furnace. The method provides a measure of piloted and non-piloted ignition temperatures of polymeric materials under controlled laboratory conditions. Values obtained represent the lowest ambient air temperatures that cause ignition under the conditions of the test and can be of considerable value in assessing and comparing the burning behaviour of materials.

C O N T E N T S

* * *

THE COMBUSTION OF ORGANIC POLYMERIC MATERIALS.

IGNITION PROPERTIES

1. INTRODUCTION

The ease with which a material can be ignited has been extensively used as a measure of its flammability [1-3]. Ignition requires (a) homogeneous mixing on a molecular level or the maintenance of continuous interfacial interactions of a fuel and an oxidiser, and (b) the temperature to be raised to a threshold point where a sufficient concentration of reactive species allows initiation of reaction in a local region. The ignition process and temperature are thus geometry and time dependent and, in the assignment of a material ignition temperature, the test method and conditions must be specified.

Ignition behaviour has also been characterised by the variation of ignition time with temperature under various conditions, from which data such as the minimum heat energy necessary to achieve ignition can be obtained [2]. In addition, Arrhenius type plots can provide more fundamental information on the nature of the ignition process [2].

In the present work, two temperatures, piloted ignition temperature and non-piloted ignition temperature, have been determined under carefully controlled laboratory conditions for a number of organic materials of interest to Navy. Other aspects of burning behaviour of similar materials have been previously reported [4-7].

2. EXPERIMENTAL

2.1 Materials

The generic names of the materials tested are listed in Table 1, together with material code numbers for "Trade-Name", manufacturer and/or supplier identification [6].

2.2 Apparatus

A hot-air ignition furnace, conforming to the requirements of ANSI/ASTM D 1929-77 and constructed at MRL, was used in this investigation. The furnace and ancillary equipment are shown in Figure 1 and details are given in the Appendix.

2.3 Test Specimens

Sample preparation, where appropriate, has been given previously [6]. Test specimens of the low density mineral fibre marine board, natural rubber latex foam, flexible poly(vinyl chloride) foam and flexible polyurethane foam contained $\sim$ 0.5 g of material. The specified weight of 3.0 $\pm$ 0.5 g was used for the remaining materials. Flexible polyurethane foam and mineral fibre marine board were cut into 12 cm^3 and 6 cm^3 blocks respectively and compressed and bound with fine wire. The remaining materials were cut into 30 mm^3 pellets for testing.

2.4 Ignition Temperature Measurements

Ignition temperatures were measured in accordance with Procedure A of ANSI/ASTM D 1929-77. The temperature of the furnace containing a test specimen is raised at an approximate rate of ΔT_2 = 600°C/h with an air flow rate of 25 mm/s. The air temperature (T_2) at which the combustion gases ignite in the presence of a pilot flame is noted. This point is evidenced by a rapid rise in the specimen temperature (T_1). This procedure is repeated at air flow rates of 50 and 100 mm/s.

The air flow is set at the rate corresponding to the minimum ignition temperature (T_2 above) and the initial air temperature (T_1) is set at (T_2-10)°C. The specimen is placed in the furnace and any ignition is observed. If ignition does occur, the procedure is repeated at 10°C lower settings until no ignition occurs in 30 minutes.

A second ignition temperature is determined by a similar procedure in the absence of a pilot flame. The externally induced ignition where the onset of flaming combustion is initiated by contact of a high temperature energy source (the pilot) with gases or volatiles from materials undergoing thermal degradation is referred to as piloted ignition [8]. Induced ignition where the onset of flaming combustion is initiated, without the presence of a pilot, by energy from an external source (radiation or convection) is referred to as non-piloted ignition. The reported minimum piloted and non-piloted ignition temperatures are the lowest furnace air temperatures (T_1) which cause ignition on insertion of the test specimen. For all materials, minimum ignition temperatures were measured at the low air flow rate of 25 mm/s. An increase in air flow rate to 100 mm/s generally raised the ignition temperatures less than 20°C. A typical recorder output during constant-temperature tests to determine minimum ignition temperatures is illustrated in Figure 2. The criteria used for ignition were the rapid combustion exotherm (D in Figure 2) as well as visual observations. The specimen temperature immediately prior to ignition is higher than the reported ignition temperature, as shown in Figure 2, predominantly due to the exothermic nature of the thermal oxidation reactions.

3. RESULTS AND DISCUSSION

The ignition temperatures of the tested materials are given in Table 1. In each case, ignition was followed by luminous flaming combustion and the emission of black smoke of varying intensity. The melamine paper laminates, mineral fibre marine board, polypropylene and flexible polyurethane foam evolved less smoke than the remaining materials.

Differences in piloted and non-piloted ignition temperatures were, in most cases, not appreciable (less than 20°C). Exceptions were limited to two classes of materials; (a) natural rubber latex adhesive and foam (ΔT = 40°C), and (b) vinyl epoxy adhesive and epoxy resin (ΔT = 90-100°C). The reproducibility of measurements was to some extent dependent on the ease of ignition (higher reproducibility at low ignition temperatures) but generally the results are accurate to ± 10°C. The fire retarded melamine paper laminate undergoes glowing as well as flaming combustion and differentiation required a very close visual inspection, resulting in greater errors (± 20°C) in the ignition temperatures.

Some limitations other than those inherent in the test method must also be recognised. For example, preliminary work showed significant changes in ignition properties of the epoxy adhesives with cure conditions. Also, the non-standard specimens of cellular materials (see Section 2.3), necessary because of their low density, should be taken into consideration. With less available fuel, a higher temperature is required for the fuel/air ratio to reach the lower flammable limit.

The ignition temperatures given in Table 1 allow identification of materials which, because of their low ignition temperatures, may exacerbate the hazard in a fire situation, as well as those which may reduce the overall hazard. It is of interest to compare the ignition temperatures of the materials with their oxygen indices (Figure 3) [5]. In general, those materials with high ignition temperatures also have high oxygen indices.

4. CONCLUSIONS

In this investigation, the ignition temperatures of particular materials of interest to Navy have been determined under controlled laboratory conditions. The values obtained can be of considerable value for comparing the ignition properties of different materials. However, the test is not intended to be, and should not be regarded as, the sole criterion for fire hazard. It must be used in association with other tests which measure other important aspects such as flame spread rate, heat production, smoke and toxic product evaluation, to provide a background for the prediction of overall fire hazard. In this regard, it is also necessary to consider material burning behaviour interaction. An assembly containing materials whose burning behaviours differ appreciably may represent a greater fire hazard than that from isolated materials. Guidelines relating the loading and proximity of flammable materials to the overall fire hazard can only be provided by large scale fire tests.

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APPENDIX

DETAILS OF HOT AIR IGNITION FURNACE AND ANCILLARY EQUIPMENT

The hot air ignition furnace (Figure 1) consists of the following parts :

1. *Furnace tube* - A vertical ceramic tube that will withstand 750°C, with an inside diameter of 100 mm, a length of 220 mm and an opening at the bottom fitted with a plug for the removal of accumulated residue.

2. *Inner ceramic tube* - A ceramic tube with an inside diameter of 76 mm, a length of 220 mm and thickness of about 3 mm, positioned inside the furnace tube 20 mm above the furnace floor on three spacer blocks. The top is covered by a disc of heat-resistant material with a 25 mm diameter opening to insert thermocouple leads, for observation and for passage of smoke and gases.

3. *Pilot flame* - A copper tube with an inside diameter of 1.6 mm, attached to a gas supply adjusted to give a 19 mm pilot flame, and positioned horizontally 6.4 mm above the disc cover so that the pilot flame is centred above the opening in the disc.

4. *Air source* - A copper air inlet tube near the top of the annular space between the ceramic tubes so that the air is heated in the space between the two tubes and enters the bottom of the inner furnace.

5. *Air flow* - A Matheson R 7600 Series flowmeter.

6. *Heating unit* - An electrical heating unit of 50 turns of No. 16 Nichrome alloy wire wound around the furnace tube and embedded in cement as well as contained within an asbestos sleeve.

7. *Insulation* - A layer of asbestos wool approximately 60 mm thick, covered by a sheet iron jacket.

8. *Specimen support and holder* - A steel container with a diameter of 40 mm, a depth of 12 mm and thickness of 0.2 mm held in a ring of 1.6 mm stainless steel rod welded to a length of the same type rod extending through the cover of the furnace. The specimen holder is located 180 to 190 mm from the top of the furnace.

9. *Thermocouples* - Chromel alumel thermocouples for temperature measurements. Thermocouple No. 1 measures the temperature of the specimen and also the initial air temperature in the furnace before insertion of the specimen (T_1). It is located as near the centre of the specimen as possible when the specimen is in place in the furnace, and is connected to a Varian A-25 chart recorder. Thermocouple No. 2 measures the air temperature in the furnace (T_2). It is located slightly below and to the side of the specimen holder and the temperature is displayed on a Comark 3010 digital thermometer.

TABLE 1

MATERIAL IGNITION TEMPERATURES

Material Code	Material (LOI)*	Minimum Piloted Ignition Temperature (°C)**	Minimum Non-Piloted Ignition Temperature (°C)**
1.3	Melamine paper laminate, standard grade (29.5)	398	433
1.4	Melamine paper laminate, fire retardant grade (58.2)	554	559
1.9	Mineral fibre marine board (46.0)	494	494
3.3	Natural rubber latex adhesive (19.8)	289	330
3.6	Epoxy resin (20.9)	315	429
3.11	Vinyl epoxy adhesive (23.3)	333	414
5.14	Flexible poly(vinyl chloride) foam (25.6)	441	441
5.16	Natural rubber latex foam (17.3)	274	310
-	Flexible polyurethane foam (DEF (A) 460) (18.1)	335	335
-	Polypropylene (17.5)	342	364
-	Flexible poly(vinyl chloride) (28.1)	422	424
6.2	Vinyl asbestos (46.9)	431	434

** Temperatures are subject to a thermocouple tolerance of ± 1%

* LIMITING OXYGEN INDEX

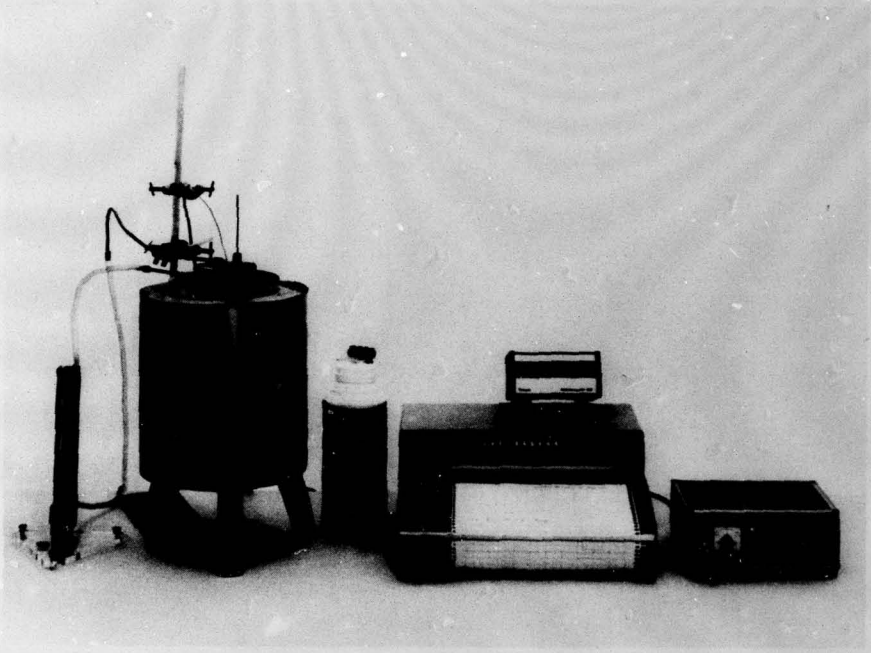

FIG. 1 - The Hot-Air Ignition Furnace and Ancillary Equipment.

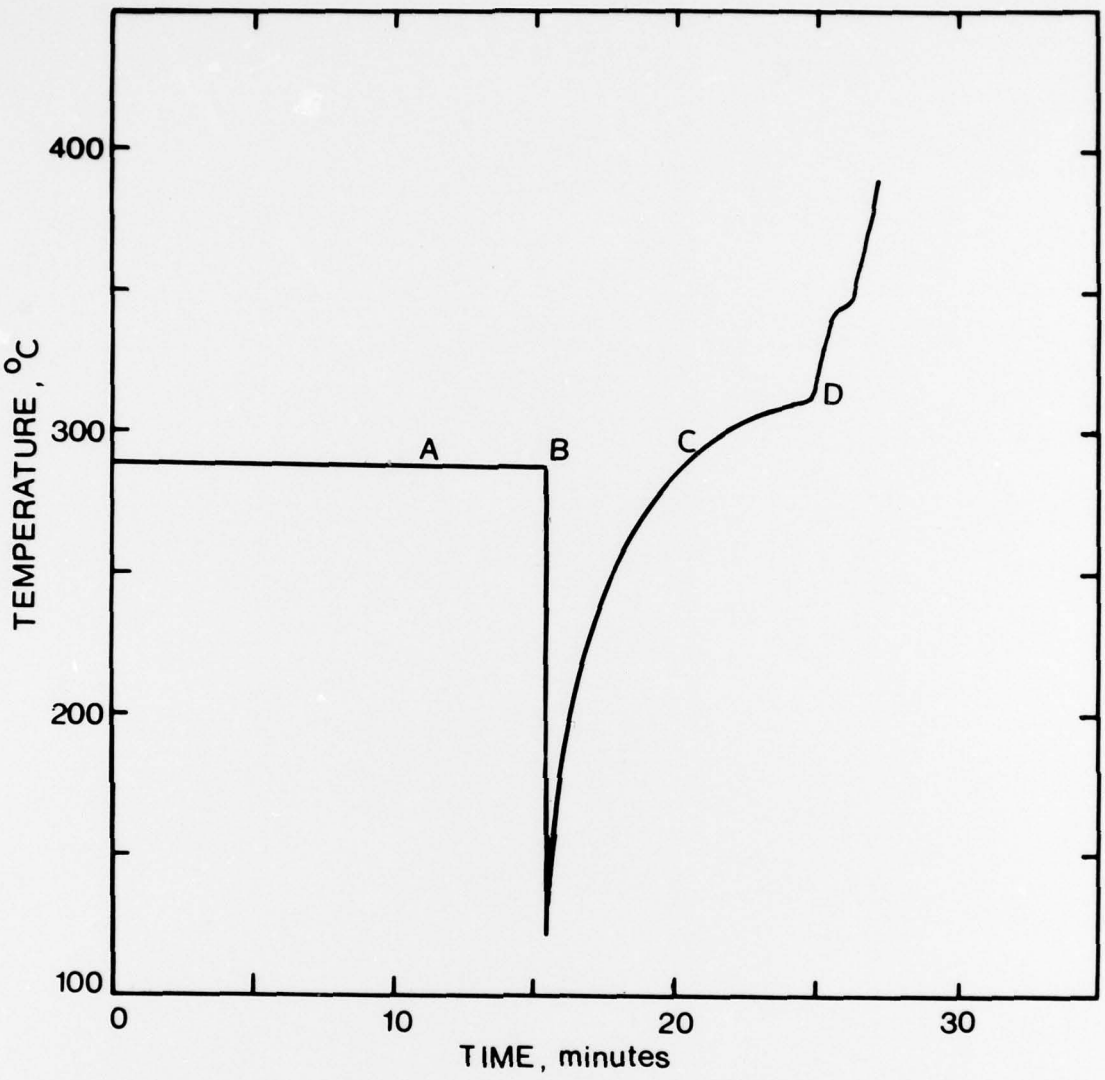

FIG. 2 - Typical Recorder Output During Ignition Temperature Determination.
(A) Furnace Air Temperature, (B) Sample Insertion Point, (C) Sample Heating, (D) Ignition Point.

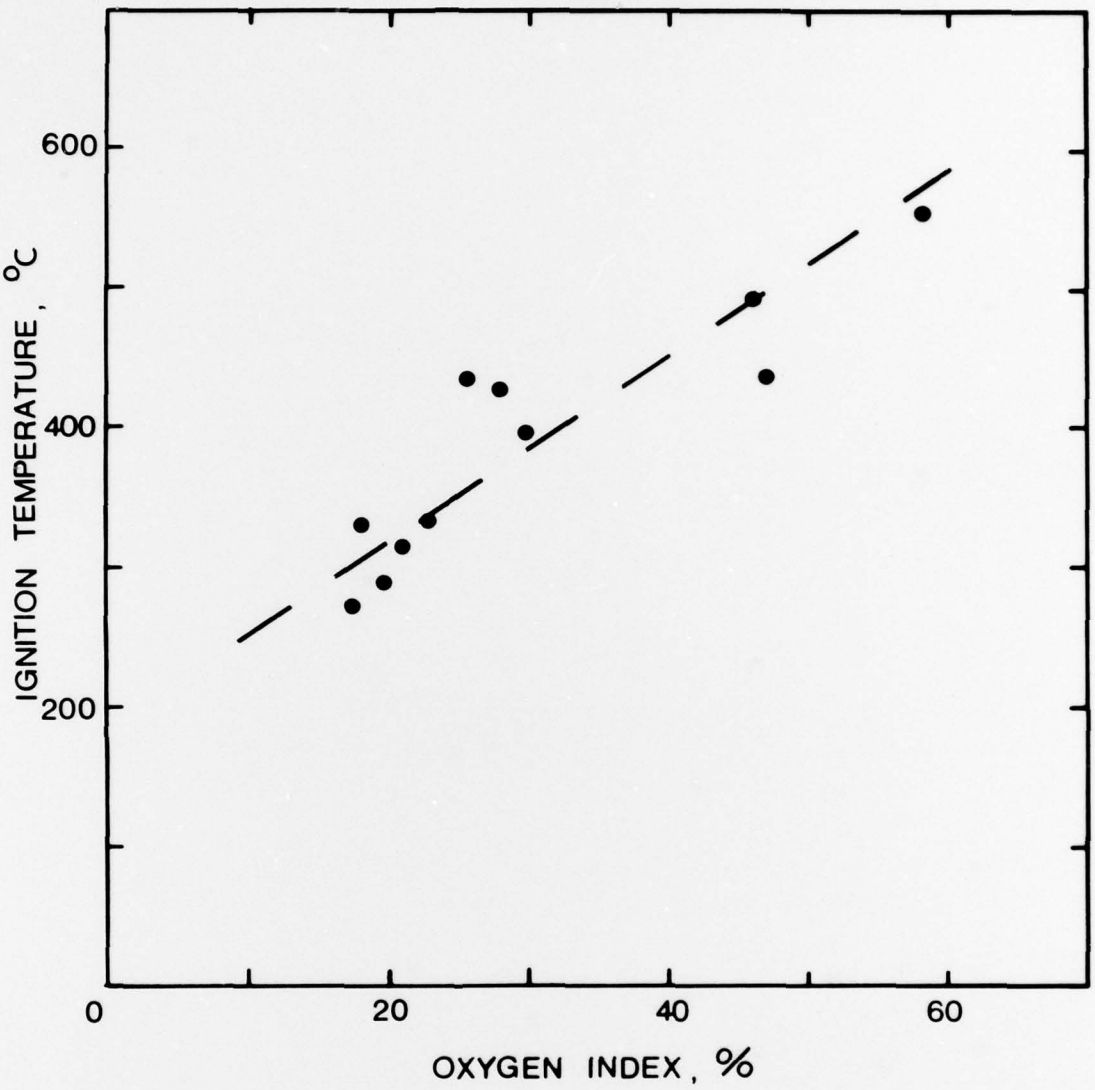

FIG. 3 - Piloted Ignition Temperature vs Oxygen Indices of Test Materials.

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